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A Review on Light Weight Self-Compacting Concrete

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ABSTRACT: Lightweight concrete (LWC) is an excellent solution in terms of decreasing the dead load of the structure, while self-compacting concrete (SCC) eases the pouring and removes construction problems. Combining the advantages of LWC and SCC is a new field of research. Considering its light weight of structure and ease of placement, Light-weight self-compacting concrete (LWSCC) may be the answer to the increasing construction requirements of slender and more heavily reinforced structural elements. In this paper, a various mix design methods and experimental study of LWSCC using different fibers are reviewed. The studies indicate that the use of light weight aggregate in SCC shows satisfactory filling ability, passing ability, segregation resistance and compressive strength.

KEYWORDS: Light weight aggregate, light weight concrete, self-compacting concrete, filling ability, segregation resistance, compressive strength.

I. INTRODUCTION

With the advancement of concrete technology, several attempts have been made in developing new high performance materials that possess the benefits and characteristics of self-compacting concrete (SCC) and light weight concrete (LWC) in the past decades. An innovative concrete, lightweight self-compacting concrete (LWSCC), which possesses the properties of both LWC and SCC has been developed. LWSCC is produced by the replacement of normal weight aggregate (NWA) with light weight aggregate (LWA) in SCC. According to ACI 213, the density of structural lightweight concrete must falls within the range of 1120 $kg/m^3$to 1920 kg/m^3. Aggregates contribute to the most of the weight of concrete and commonly constitute about 60% by volume of SCC. As such, due to the porous structure of LWA, it is able to reduce the density as well as the thermal conductivity of concrete. The use of LWSCC brings about several benefits such as reduced self-weight, shorter construction period, lower construction cost and elimination of noise emitted from vibration machines as well as better heat and sound insulation due to the voids in LWA. Since the present construction industry is experiencing the shortage of skilled workers as well as the difficulty in hiring new generation of skilled workers, LWSCC which is less labour intensive, can be a timely solution to these shortcomings. In addition, LWSCC, which is very suitable for manufacturing precast units, can be used to promote mechanization or even automation processes in construction industry.

II. LITERATURE REVIEW

T.Z.H. Ting et al. (2019) studied the physical properties of lightweight aggregates used in developing mix design of lightweight self-compacting concrete and the methods to develop Lightweight Self-Compacting Concrete (LWSCC) mix design with anticipated fresh and hardened concrete. In this study, research shows that the mix design of LWSCC is preferably proportioned by aggregates packing concept. They highlighted that the close aggregate packing principle provides clear insight into the understanding of consumption of aggregate and paste volume for a given unit volume of concrete.

Michael Kaffetzakis et al. (2016) introduced a rational mix design methodology for Lightweight Aggregate Self-Compacting Concrete (LWASCC) based on the Optimum Packing Point (OPP) procedure. In this study, a series of 17 Pumice Aggregate Self-Compacting Concrete (PASCC) mixtures were produced based on the OPP procedure; their key mix design parameters were then statistically correlated to selected fresh and hardened properties is achieved. In this research, the methodology was verified through the

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production of a limited number of PASCC mixes that satisfied their preset design performance values.

Miguel C.S. Nepomuceno et al. (2018) studied the mix design of structural lightweight self-compacting concrete (LWSCC) incorporating coarse lightweight expanded clay aggregates and natural sand. In this study, it was concluded that the coarse aggregates reference curve, as well as the mortar phase flow properties proposed by Nepomuceno et al. (2012) for the SCC, are adequate to produce LWSCC. Correlations to quantify the volume of coarse lightweight aggregates (Vg) are presented. It was shown that Vg depends on the mortar phase proportions, concrete workability properties, concrete compressive strength and concrete oven dry density. The researchers proved that the analysis of dynamic and static segregation shows a satisfactory performance with a uniform distribution of lightweight aggregate.

Jingjun Li et al. (2017) proposed a simple mix design method for lightweight aggregate self-compacting concrete (LWASCC) based on the packing and mortar film thickness (MFT) theories. In this study, five mixture proportions with varying MFT (i.e., 1.4, 1.6, 1.8, 2.0 and 2.2 mm) were designed. The results showed that the proposed mix method is an effective method to develop LWASCC. They found that the flow-ability increases with the increase of MFT and the compressive strength at 28 d and 56 d shows a contrary variation tendency compared with its early ages, which is attributed to the stiffness difference between aggregates and mortar at different age. Then, the splitting tensile strength of MT-1.4 is higher than that of MT-1.6. With the increase of MFT ranging from 1.6 mm to 2.2 mm, the splitting tensile strength increases due to the decrease in the quantity of aggregate content and the positive effect of MFT on the aggregate/paste interface.

Behnam Vakhshouri et al. (2016) investigated the twenty one laboratory experimental investigations on the mix proportion, density and mechanical properties of LWSCC have been published in the last 12 years and the collected information is used to investigate the mix proportions including the chemical and mineral admixtures, light weight and normal weight aggregates, fillers, cement and water. In this paper, analysed results are presented in terms of statistical expressions. The researchers found that it is very helpful to choose the proper components with different ratios and curing conditions to attain the desired concrete grade according to the planned application.

Klaus Holschemacher et al. (2017) investigated the steel fibre reinforced high strength lightweight self-compacting concrete (SHLSCC) is applied for the strengthening of RC beams to improve their bending moment capacities. The researchers found that there are significant improvements in stiffness of strengthened beams as well as 14 - 58 % improvements in peak load when strengthened with 40 mm, 50 mm and 60 mm layers of SHLSCC and the results indicate that the material may effectively be utilized for strengthening of bending members in existing structures.

K. Poongodi et al. (2020) investigated the potential enhancement of impact strength due to the addition of banana fibre in structural lightweight self-compacting concrete (LWSCC). In this study, the coconut shell was substituted instead of coarse aggregate partially to develop the lightweight concrete. The researchers found that there is no undesirable effect on the self-compatibility because of the addition of banana fibre and had shown the significant improvement in compressive strength and the additions of 1.25% banana fibres improve impact strength of LWSCC.

Ibrahim Saad Agwa et al. (2020) examined the mechanical properties and microstructure of lightweight self-compacting concrete (LWSCC) incorporating rice straw ash (RSA) and cotton stalk ash (CSA) as a replacement ratio by weight of cement content. In this study, the pumice lightweight coarse aggregate is used as a replacement for normal weight coarse aggregates with a ratio of 80%. The researchers found that the workability of LWSCC is decreased as the RSA and CSA ratios increased. By contrast, the hardened properties of LWSCC are increased as the percentages of RSA and CSA increased, except for 20% replacement ratio. The scanning electron microscope analysis shows that 10% of RSA yielded a denser concrete than the control mix.

Thiago Melo Grabois et al. (2016) summarized the results of a comprehensive experimental characterization on the fresh and hardened state of self-compacting lightweight concrete (SCLC) reinforced with steel fibres. In this study, two classes of SCLC were produced containing either coarse or coarse and fine lightweight aggregates. Steel fibres were used as reinforcement in fibre volume fraction of 0.5%. The researchers found that fibre reinforcement has increased the mechanical properties under direct tensile and bending tests.

Nahla Naji Hilal et al.(2020) investigated Walnut Shell (WS) was used as a replacement of coarse aggregate for constructing SCC by employing ten different volume fractions from 5% to 50% with each increment of 5%. In this study, Fresh and hardened properties of SCC were investigated for all mixes and control one. The researchers found that the lightweight self-compacting concrete (LWSCC) can get at fraction volume of WS equal and or more than 35%. Where, slump flow diameter (SFD), compressive and bond strengths were 560 mm, 35 MPa and 6.55 MPa respectively achieved at 35% ratio of WS.

K.M.A. Hossain et al. (2020) investigated the durability of FRLWSCC beams through accelerated corrosion testing. In this study, both corrosion resistance and structural performance of fibre reinforced light weight self-compacting concrete (FRLWSCC) beams were evaluated and the structural response of un-corroded beams was also assessed and compared with their corroded counterparts. The researchers found that the LWSCC-HDPE beam exhibited superior corrosion resistance as compared to LWSCC-PVA and LWSCC-CR beams. The LWSCC-HDPE beam experienced a lesser amount of mass loss of reinforcement, fewer cracks and less spalling.

Vahab Naderi Zarnaghi et al. (2018) studied the pore structure of lightweight self-compacting concrete with different amounts of silica fume and water-to-cement ratios. In this study, the fractal characteristics of the pore structures were studied, and the pore mass and solid mass fractal dimensions were calculated based on well-established methods. . The results have showed that compressive strength and water penetration depth increase with the increase of fractal dimension and have good correlation with fractal dimensions.

III. FRESH PROPERTIES OF LWSCC

T.Z.H. Ting et al. (2019) reported that the workability of LWSCC is highly dependent on the aggregates packing density and void volume. In general, similar to normal SCC, the performance of LWSCC workability with respect to filling ability, passing ability and segregation resistance is greatly influenced by water to binder ratio, super plasticizer dosage and total binder content. The inclusion of different types of supplementary materials has different effects on LWSCC workability. When silica fume is used, and with increasing replacement level, the segregation resistance of LWSCC is found to be improved while it has negative effect on filling and passing ability. The inclusion of fly ash as binary or ternary blend can not only improve all the three fresh properties but also reduce the amount of SP required. In addition, the incorporation of fibers such as steel and synthetic fibers is able to improve the filling ability but it causes negative effect on passing ability.

IV. HARDENED PROPERTIES OF LWSCC

T.Z.H. Ting et al. (2019) reported that the compressive strength of LWSCC is mainly governed by the homogeneity of the batched concrete. The uniformity and homogeneity of LWSCC are governed by the mixing time and procedure. Since the mortar of LWSCC is normally stronger than LWA, the compressive strength of LWSCC is also dependent on the strength and proportion of LWA. The compressive strength of LWSCC is sensitive to changes in mix component properties and their proportions such as water to binder ratio, binder content and the incorporation of supplementary cementitious materials. These factors must be considered properly in mix design in order to achieve anticipated workability in fresh state and compressive strength in hardened state. The optimum implementation of supplementary materials such as fly ash, slag and silica fume can improve compressive strength. In addition, the incorporation of fibres such as steel, synthetic and macro fibres will increase compressive strength of LWSCC.

V. CONCLUSIONS

The following conclusions are made by reviewing the literature:

- Water/cement and water/total powder ratios vary between 0.25–0.85 and 0.25–0.5 respectively.
- Different ranges of chemical admixtures have been used in the mixes, however despite the inclusion of super plasticizer in the mixes; the air entraining agent and viscosity modifying agent are not used in all LWSCC mix designs
- The weight ratio of cement, mineral powder and the combined weight of cement and mineral powder to the mix weight vary between 9.44 and 29.77%, 1.26 and 15.79% and 18.98–42.53% respectively in all the LWSCC mix designs.
- Fillers and cement are two types of powder applied in all LWSCC mix designs. The variation of filler types is more than that of the cement types in the LWSCC mix designs.
- The incorporation of fibres improves the compressive strength and filling abilities but it had shown negative effect on passing ability.

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